

THE REMOVAL OF OIL DROPLETS FROM GAS STREAMS

BY

FRANK OSCAR EKMAN

B.A.Sc., University of British Columbia, 1944

M.A.Sc., University of British Columbia, 1946

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY IN CHEMICAL ENGINEERING
IN THE GRADUATE COLLEGE OF THE
UNIVERSITY OF ILLINOIS, 1950

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INTRODUCTION

New units have recently been developed to meet the need for cheap, reliable equipment for removal of small aerosol particles. One of these new developments is the cyclone spray scrubber, or Pease-Anthony tower, another is the ultrasonic precipitator. Still a third is the venturi scrubber which operates efficiently over a wide range of particle sizes and concentrations. The venturi scrubber consists of a conventional venturi into which the scrubbing liquid is introduced at the throat, followed by a cyclone or cyclonic tower which removes the liquid and its aerosol content. The variables affecting aerosol removal by the venturi scrubber were studied in this investigation.

THEORY

Aerosol particles may be removed from gases by the mechanisms of impaction, diffusion, or enmeshment. The efficiency of removal by impaction is a function of the group μ/kD , in which m is the mass of the particle, u its velocity, k Stokes' Law resistance coefficient, and D the diameter of the water droplet or other object upon which the particle impinges. As smaller values of the group give smaller efficiencies, removal is more difficult for smaller sized particles.

Greater efficiencies can be obtained by increasing u or decreasing D . Greater velocities and smaller water drops can be obtained in the venturi scrubber than in most other scrubbing units.

If the aerosol particle is small enough to exhibit Brownian movement, the mechanism of diffusion, analagous to gaseous diffusion, becomes important. Consequently, extremely small particles can be collected easily. The efficiency of aerosol

removal is a function of the specific drop surface, S , in both the mechanism of impaction and that of diffusion. Owing to the high relative air-to-water velocities in the venturi throat, the water stream is broken up into fine, cobweblike filaments which are then torn apart to form drops. Possibly at least some of the aerosol particles are physically enmeshed by these twisting filaments. Both aerosol particles and water drops formed by atomization carry electrostatic charge. These charges were not investigated, but the efficiency of removal may be modified by their presence.

EXPERIMENTAL

The venturi used in this investigation was made of Plexiglass so that the atomization of water could be observed. The venturi was attached to 3-inch pipe by flanges; the convergent angle was 25 degrees, and the divergent angle 7 degrees. The throat was $1 \frac{3}{16}$ inches in diameter and $1 \frac{1}{2}$ inches long.

Water was introduced axially, along the axis of the throat, radially outward, from a central pipe with four holes directed along radii, and radially inwards, from one nozzle in the side of the throat. The water spray was removed by a cyclone.

The aerosol was generated by mixing dibutylphthalate oil and very hot air at the throat of a small venturi. The vapor formed was rapidly condensed in the main air stream. The three sizes of oil droplets used were 0.8 and 1.0 micron droplets, which were uniform, and 5.5 micron droplets, which were not.

The efficiency of aerosol removal was determined by analysis of the air ahead of the venturi and sampling the water-aerosol mixture removed by the cyclone. The aerosol sampling train consisted of three glass-wool filters in series, an orifice meter, and a wet-test meter. The orifice meter was used to determine sampling rates for isokinetic sampling and the wet-testmeter to accurately measure the total air sampled. A cumulative sample of water was collected from the cyclone. The oil was removed by extraction with ether which was then

evaporated at a low temperature. Sampling of the air after the cyclone was possible only at low water rates, but this method checked the results obtained by ether extraction. Particle size was determined by microscopic examination of the droplets, collected by a high velocity impactor. A spread factor of 2.0 was used. Data obtained with an improvised form of LaMer's Owl qualitatively confirmed the microscopic investigation.

The experimental results show that large particles are removed more easily than smaller ones. Each method of water injection gave different results. When radial outward injection was used the removal efficiency was a function of S only, and not of the throat velocity, u_2 . When the other two methods were used, removal efficiency was a function of the product Su_2 . Correlations for removal efficiency versus pressure drop show that, for a given removal efficiency, the pressure loss is usually less for the lower throat velocities. The pressure loss across the venturi, plotted as the number of throat velocity heads, is a function of the ratio of liquid to air. For axial injection the correlation is not a straight line; for the other methods of injection it is. Removal efficiencies were low when the aerosol concentration was less than normal. The drop size distribution for the large non-uniform particles does not follow a normal probability curve.

CONCLUSIONS

The following conclusions may be reached: The removal efficiency is affected by aerosol particle size, aerosol concentration, method of water injection, and throat velocity. The method of water injection affects the pressure loss; axial water injection causes the least loss and radial inward the greatest. Within the range of data taken, a given removal efficiency can be produced at less pressure loss by the use of large quantities of water and low throat velocities than by high throat velocities and small quantities of water.

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VITA

The author, Frank Oscar Ekman, was born in London, England, on March 26, 1917. He attended Telkwa Public School, in Telkwa, British Columbia, Canada, from 1923 to 1930, and Telkwa High School from 1930 to 1934. In 1939 he entered the University of British Columbia in Vancouver, and graduated from this institution in 1944 with a B.A.Sc. in Chemical Engineering. During this period he held a Leonard Foundation scholarship. He returned to the University of British Columbia in 1945, and in 1946 received an M.A.Sc. degree in Chemical Engineering. He attended the University of Illinois from 1946 to 1949. During the period 1946 to 1948 he held a graduate research assistantship in Chemical Engineering in the Engineer-Experiment Station.



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